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GEOPHYSICS.—*The density of the Earth as calculated from the densities of Mauna Kea and Haleakala.* HENRY S. WASHINGTON, Geophysical Laboratory.[1]

Of the various methods for determining the mean density of the Earth the oldest is that of measuring the attraction exerted by an isolated mountain. This was employed at Chimborazo by Bouguer as early as 1749, next at Schiehallion by Maskelyne and Hutton in 1775, and later by others at other mountains.[2] The method is open to very serious objections, as pointed out by Boys; difficulty in measuring the geometrical form and mass of the mountain, and ignorance or uncertainty as to the homogeneity or distribution in heterogeneity, the solidity of the mountain, and the character of the underlying crust of the Earth. This method, indeed, has been superseded by those based on laboratory experiment, such as with the torsion balance or the chemical balance.

The last geodesist to use the "mountain observation" method for the determination of the mean density of the Earth (Δ) was E. D. Preston, of the U. S. Coast and Geodetic Survey, in connection with pendulum and latitude observations at Mauna Kea on the Island of Hawaii[3] in 1892.

In the course of a recent petrological study of the lavas of the Island of Hawaii I determined the specific gravities of the specimens that I analysed, including those of Mauna Kea,[4] and was struck with the discrepancies between my specific gravities and their average and those given by Preston, as well as the resulting values for the density of the Earth.

[1] Received Nov. 26, 1923.

[2] Cf. C. V. Boys in Glazebrook, A dictionary of applied physics, **3**: 279. 1923.

[3] E. D. Preston, U. S. Coast and Geodetic Survey, Report for 1893, Appendix No. 12, pp. 625–634. 1894.

[4] H. S. Washington, Amer. Journ. Sci. **5**: 487–502. 1923; and Amer. Journ. Sci. **6**: 361. 1923.

The specimens of lava that Preston collected at Mauna Kea were examined by Merrill,[5] who determined the specific gravities of fourteen of them, the average being 2.63. This is very low and is accounted for by the fact that many of the specimens were vesicular or not fresh, as pointed out by Merrill. From his pendulum observations and estimates of the altitude and radius of the base of the mountain, Preston calculates the value $\delta = 0.565\Delta$; in which δ is the average density of the rocks and Δ is the average density of the Earth. The value given is the mean between those arrived at on the assumption that the attraction of the mountain is the mean between that of an infinite plane and of a cone. Using Merrill's average specific gravity the mean density of the Earth is, therefore, calculated to be 4.655, a figure far below the accepted value. Preston, however, does not use Merrill's data alone but combines these with the specific gravities of lavas from Mauna Loa and Kilauea, as determined by E. S. Dana.[6] He thus arrives at the average Mauna Kea rock specific gravity 2.90 and the value 5.13 for the mean density of the Earth, this last being also much below that generally accepted, which may be taken as 5.52.[7]

I determined the specific gravities of nine specimens of the Mauna Kea rocks, some of whole hand specimens with the balance and others of the rock powder with the pycnometer.[8] The results, with two determined by Daly,[9] are given in Table I, with the calculated densities. The specific gravity No. 1 (2.870) is a new determination of that of the andesite of Laupahoehoe, the previously published value (2.709)[10] having been too low because of the vesicularity of the specimen. No. 10 (2.959), of the olivine basalt of Kaula Gulch, is also new. These results give an average specific gravity of 2.969 and an average density of 2.963; hence, using Preston's value $\Delta = 1.77\delta$, $\Delta = 5.245$. This is much higher than the value (4.655) obtained from the specific gravities of Preston's specimens, and somewhat higher than that (5.13) calculated by Preston, but is still much below the generally accepted value.

Regarding these results some comment is called for. Preston seems to have selected more or less vesicular specimens because he

[5] G. P. Merrill in Preston, *op. cit.*, 630.

[6] E. S. Dana, Amer. Journ. Sci. **37**: 441. 1889.

[7] Cf. the value (5.525) selected by Burgess (Boys in Glazebrook, *op. cit.*, p. 285); also Williamson and Adams, Journ. Washington Acad. Sci. **13**: 413. 1923.

[8] The pycnometer determinations on the rock powder are consistently higher than those made on the hand specimens.

[9] R. A. Daly, Journ. Geol. **19**: 208 and 301. 1911.

[10] H. S. Washington, Amer. Journ. Sci. **5**: 490. 1923.

appears to have thought, judging from the conspicuous flows on the surface, that they represented well the bulk of the rocks of the volcano. In this I think that he is in error, because my examination of the deep ravines cut by erosion in the eastern flank of Mauna Kea showed "the almost complete absence of ash and scoria beds" and the overwhelming prevalence of compact or but very slightly vesicular forms of lava among the interior flows. It is therefore probable that my specimens, most of which were compact or in which vesicularity was compensated for by pulverization, represent the mass of the volcano far better than do Preston's surface specimens of pahoehoe or the rough aa crust, conspicuous forms that a non-geologist would naturally collect.

In the next place, Preston seems to be scarcely justified in using Dana's data for Mauna Loa and Kilauea in discussing the density of Mauna Kea. My recent study has shown that the general petrographical and chemical characters and the average densities of the five volcanoes on Hawaii are markedly different the one from the other. Thus, to confine our attention only to densities, I obtained the average specific gravity 2.969 for Mauna Kea, 2.932 for Kilauea, 2.953 for Mauna Loa, and 2.940 for the whole island of Hawaii. The differences are not great, but they are so marked that they should be taken into account.

Five years earlier than his study at Mauna Kea, Preston,[11] from pendulum observations at Haleakala on Maui, obtained the value $\delta = 0.48\Delta$ at this volcano, which was considered as a cone. From this, accepting the value of Δ as 5.67, he calculates the average density of the rocks of Haleakala as 2.72.

This average specific gravity seems much too low, and that derived from the specimens that he collected, (2.21) is certainly far below the true value, as may be seen from the individual specific gravities and from Merrill's descriptions, which indicate that most of Preston's Haleakala specimens were either very vesicular or not fresh. I have therefore determined the densities of nine specimens of lava from Haleakala that were collected in 1920 by Dr. J. Allan Thomson and kindly given by him to me for study.[12] The freshest, most compact, and the most representative specimens, so far as could be judged without microscopical examination, were selected. The determina-

[11] E. D. Preston in U. S. Coast and Geodetic Survey, Report for 1888, Appendix No. 14, p. 530. 1889. He gives a slightly lower value (0.43) in Amer. Journ. Sci. **36**: 311. 1888.

[12] These will be described, with analyses, in a forthcoming paper in my series on the petrology of the Hawaiian Islands.

tions were all made on whole hand specimens with the balance, inclosed air being expelled by exposure in water to a pressure of about 2 cm., and subsequent soaking for eight hours before weighing in water.

The results, given in Table I, indicate that the average density of the rocks of Haleakala is 2.812, which is markedly lower than that of Mauna Kea (2.963). From this Haleakala density the mean density of the Earth, using Preston's value $\delta = 0.48\Delta$ for Haleakala, would be 5.877, a figure that is about as much above the accepted value as that derived from the Mauna Kea data is below it. The average of the two values for Δ, based on my specimens from Mauna Kea and Haleakala, is 5.560, which is fairly close to the accepted value.

TABLE I

MAUNA KEA			HALEAKALA		
Sp. gr.	C°	Density	Sp. gr.	C°	Density
2.870	21°	2.864	2.706	25°	2.698
2.911	(Daly)	2.911	2.734	25°	2.726
2.761	(Daly)	2.761	2.924	25°	2.915
2.982	22.3°	2.976	2.836	25°	2.828
3.040	22°	3.033	2.929	25°	2.920
3.018	22.3°	3.010	2.788	25°	2.780
2.994	22.3°	2.987	2.718	25°	2.710
2.972	17°	2.968	3.067	25°	3.058
2.978	22.3°	2.971	2.680	25°	2.672
2.959	20.2°	2.954			
3.164	25°	3.158			
Average 2.969		2.963	2.820		2.812

SCIENTIFIC NOTES AND NEWS

The death is announced of Rev. JOHN THOMPSON HEDRICK, at St. Andrew-on-Hudson, Poughkeepsie, N. Y., October 24. Dr. Hedrick was formerly director of the Georgetown University Observatory. He was a generous contributor to astronomical publications and an accepted authority on the subjects upon which he wrote.

A "get together meeting" of the Society of the Sigma Xi of Washington and vicinity was held at the Cosmos Club on November 22, 1923. Ten-minute talks on *The most interesting thing I have seen the past summer* were made by various members, including L. O. HOWARD on the Wellcome Medical Historical Museum in London, PAUL BARTSCH on under-water "movies" in the Bahamas, H. L. SHANTZ on botanical excursions in Switzerland, E. E. SLOSSON (president of the local Society) on electrification in Sweden, W. T. LEE on the newly explored enormous caves in New Mexico, E. D. BALL on petrified forests in the Bad Lands. CHARLES BROOKS, of the Department of Agriculture is secretary.

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